

## TITLE OF THE INVENTION

DVD-AUDIO DISK, AND APPARATUS AND METHOD FOR PLAYING THE  
SAME

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a digital versatile disk (DVD), and an apparatus and method for playing the DVD, and more particularly, to an audio DVD (hereinafter referred to as "DVD-Audio") and an apparatus and method for playing the same.

### 2. Description of the Related Art

Recently, there has been developed a so-called video DVD (hereinafter referred to as "DVD-Video"), which has a considerably higher storage capacity than a laser disk (LD) so as to realize a significantly improved picture and sound quality. If the DVD is employed to store and retrieve only audio data, such DVD is called a DVD-Audio. The DVD-Audio provides means for storing and retrieving a large amount of audio data having a significantly improved quality compared to a compact disk (CD) or a digital audio tape (DAT).

The conventional CD stores an audio signal as linear pulse code modulated (PCM) audio data quantized into 16 bits by employing a sampling frequency of 44.1 KHz. The digital data stored in the CD is converted into analog signals by means of a CD player. The CD is much more convenient to use as compared to the previous microgroove phonograph record (LP), but is regarded as having a lower sound quality than the analog LP. This is because the audio signals are sampled at 44.1KHz and quantized into 16 bits to be stored into a CD. Moreover, the audible frequency range may be over 20KHz, and the dynamic range must be over 120dB. In addition, the CD can only store audio signals of at most two channels, and therefore is impossible to store and reproduce the audio data concerned with multi-channel music. In

these circumstances, there have been proposed various methods to improve the sound quality of the CD by increasing the numbers of the sampling frequency and the audio channels.

5 The DVD provides means to record video and audio data at high density. In this case, the video data is recorded in the MPEG (Moving Picture Expert Group) while the audio data is recorded in the linear PCM format, dolby AC-3 format, MPEG format, etc. Hence, the DVD-Video player is designed to reproduce both video and audio data recorded in a DVD-Video.

10 Such a DVD-Video prepared to necessarily store video data is very uneconomical in view of the storage space when used for storing audio data only.

15 The audio data recorded in a DVD-Video has a much higher quality than that in a CD since the audio data of the DVD has a higher sampling frequency and larger numbers of quantization bits and channels than that of the CD. Namely, the DVD player reproduces high quality audio data in multiple channels.

20 The DVD is possible to transfer data at 10.08Mbps at most. This makes it possible to reproduce data sampled at 192KHz in two channels. This also approaches the maximum sampling frequency proposed as a prerequisite for the next advanced audio system at the Advanced Digital Audio Conference held in Japan in April, 1996. Thus, if audio data are recorded in a DVD-Audio, the DVD player may reproduce sounds of a significantly improved quality  
25 over that reproduced from the DVD-Video.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a DVD-Audio for storing digital audio signals sampled at the maximum sampling frequency and quantized in the maximum number of bits with the number of channels limited by the data transfer speed in linear PCM.

It is another object of the present invention to provide a DVD-Audio for compressively coding digital audio signals sampled at the maximum sampling frequency and quantized in the maximum number of bits and storing them with the number of channels limited by the data transfer speed and the coding system in linear PCM.

It is still another object of the present invention to provide a DVD player for playing a DVD-Audio recorded in linear PCM and a method therefor.

It is a further object of the present invention to provide a DVD player for playing a DVD-Audio recorded with audio data compressively coded and a method therefor.

It is further another object of the present invention to provide a DVD player for properly playing a DVD-Video or DVD-Audio by distinguishing them.

According to a first aspect of the present invention, a DVD-Audio includes a data zone for storing data to be reproduced and an information zone for storing information on the data, the information zone including directories of a video title set (VIDEO\_TS) and an audio title set (AUDIO\_TS), wherein the AUDIO\_TS directory includes information on an audio manager (AMG) having information on audio titles, wherein the data zone includes the audio titles each having audio title set information (ATSI) followed by a plurality of contiguous audio objects (AOBs), the ATSI includes a plurality of audio stream attributes each having an audio coding mode indicator, first to third quantization bit numbers, first to third sampling frequencies and decoding algorithm information relating to the number of audio channels, and each of the AOBs includes a plurality of audio

packs recorded with audio data corresponding to the decoding algorithm stored in the audio stream attribute.

According to a second aspect, an apparatus for playing the inventive DVD-Audio includes a data receiver for receiving the audio data retrieved from the DVD-Audio, a controller for generating an audio control signal containing an audio coding mode indicator, a sampling frequency, a channel number and quantization information by analyzing information on the audio data or stopping the playing operation according to whether the AUDIO\_TS is detected to have effective data, an audio decoder to decode the received audio data and to multi-channel mix, sampling-frequency convert and requantize the decoded audio signal according to the audio control signal, and an audio output circuit to convert the decoded audio data into an analog audio signal.

According to a third aspect, a method for playing the inventive DVD-Audio includes the steps of locating the AMG when the AUDIO\_TS directory includes an effective data, checking out all information of the DVD-Audio from the information of the AMG, reading the data of the position of an audio title selected according to the position information of the AMG when receiving a command for reproducing the audio title, and setting the audio decoder to carry out the algorithm for reproducing the audio title by reading the audio stream attribute of the audio title set information management table (ATSI\_AMT).

The present invention will now be described more specifically with reference to the drawings attached only by way of example.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an example of the directory structure of a DVD;  
FIG. 2 is an example of the logical data structure of a DVD;  
FIG. 3 is a diagram for illustrating the structure of the video manager (VMG) and VTS;

FIG. 4 is a diagram for illustrating the structure of the VMG of a DVD;

FIG. 5 is a diagram for illustrating the structure of a title search pointer table (TT\_SRPT) of a DVD;

5 FIG. 6 is a diagram for illustrating the structure of a video title set information (VTSI);

FIG. 7 is a diagram for illustrating the structure of a video title set management table (VTSI\_MAT);

10 FIG. 8A is a diagram for illustrating the structure of the video title set audio stream attribute table (VTS\_AST\_ATRT);

FIG. 8B is a diagram for illustrating the internal structure of VTS\_AST\_ATRT;

15 FIG. 9A is a diagram for illustrating the structure of a multi-channel audio stream attribute table of a video title set (VTS\_MU\_AST\_ATRT);

FIG. 9B is a diagram for illustrating the structure of a multi-channel audio stream attribute (1) of a video title set (VTS\_MU\_AST\_ATR(1));

20 FIGS. 9C and 9D are diagrams for illustrating the structure of the VTS\_MU\_AST\_ATR(2);

FIG. 10 is a diagram for illustrating a logical structure of the DVD-Audio;

FIG. 11 is a diagram for illustrating the structures of an audio manager (AMG) and audio title set (ATS) of the DVD-Audio;

25 FIG. 12 is a diagram for illustrating the structure of an audio manager information (AMGI) of the DVD-Audio;

FIG. 13 is a diagram for illustrating the structure of a title search pointer table (TT\_SRPT) of the DVD-Audio;

30 FIG. 14 is a diagram for illustrating the structure of an audio title set information (ATSI) of the DVD-Audio;

FIG. 15 is a diagram for illustrating the structure of an audio title set information management table (ATSI\_MAT) of the DVD-Audio;

FIG. 16 is a diagram for illustrating the internal structure of an audio stream attribute of an audio title set menu (ATSM\_AST\_ATR) of the DVD-Audio;

FIG. 17A is a diagram for illustrating the structure of an audio stream attribute table of an audio title set (ATS\_AST\_ATRT) of the DVD-Audio;

FIG. 17B is a diagram for illustrating the structure of an audio stream attribute of an audio title set (ATS\_AST\_ATR) of the DVD-Audio;

FIG. 18A is a diagram for illustrating the structure of a multi-channel audio stream attribute of an audio title set (ATS\_MU\_AST\_ATR) of the DVD-Audio;

FIG. 18B is a diagram for illustrating the structure of a first extension of a multi-channel audio stream attribute of an audio title set (ATS\_MU\_AST\_ATR\_EXT(1)) of the DVD-Audio;

FIG. 18C is a diagram for illustrating the structure of a second extension of a multi-channel audio stream attribute of the audio title set (ATS\_MU\_AST\_ATR\_EXT(2)) of the DVD-Audio;

FIG. 19 is a diagram for illustrating the structure of an audio object set (AOBS) of the DVD-Audio;

FIG. 20 is a diagram for illustrating a pack structure of the DVD-Audio;

FIGS. 21A to 21D are diagrams for illustrating various pack structures of the DVD-Audio;

FIG. 22 is a diagram for illustrating a linear PCM audio packet in the audio pack as shown in FIG. 21A;

FIG. 23 is a diagram for illustrating the structure of a linear PCMA audio frame of the DVD-Audio;

FIGS. 24A to 24C are diagrams for illustrating a sample data arrangement of the linear PCM;

FIG. 25 is a diagram for illustrating the structure of a linear audio packet of the DVD-Audio;

FIG. 26 is a diagram for illustrating the structure of a DTS audio packet of the DVD-Audio;

FIG. 27 is a block diagram for illustrating the functional structure of a DVD-Audio player according to a first embodiment of the present invention;

FIG. 28 is a block diagram for illustrating the structure of an audio decoder as shown in FIG. 27;

FIG. 29 is a block diagram for illustrating the functional structure of a DVD-Audio/DVD-Video player according to a second embodiment of the present invention;

FIG. 30 is a block diagram for illustrating the structure of an audio/video decoder as shown in FIG. 29;

FIG. 31 is a flow chart for illustrating the process of reproducing audio data from a DVD-Audio in the DVD-Audio player; and

FIG. 32 is a flow chart for illustrating the operation of an audio decoder in the DVD-Audio player.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the attached drawings, the same reference numerals are used to represent parts serving the same functions and detailed descriptions are omitted concerning the parts not essential to describe the inventive concept, for convenience's sake.

The data structure of the DVD-Audio is similar to that of the DVD-Video. Hence, the DVD-Audio includes a data zone to record the audio data and an information zone to record the information on the audio data. The DVD player may be embodied in the form of a DVD-Audio player or a DVD-Audio/Video player. Of course, the DVD player has a mechanism to determine whether an inserted DVD is a DVD-Audio or DVD-Video. The inventive DVD-Audio has almost the same structure as the DVD-Video with some partly changed data structure to achieve the audio data of high quality.

The fundamental file structure recorded in the information zone of the DVD-Audio is as shown in FIG. 1 for illustrating a directory structure for the DVD-Video and DVD-Audio. The directory structure generally includes a video title set

directory (VIDEO\_TS), audio title set directory (AUDIO\_TS) and a user defined directory. Each of the directories contains a plurality of files of which the names shall be assigned. The directory structure is to represent the locations of the files in the disk. The files connected to the VIDEO\_TS are prepared for the DVD-Video and DVD-Video player while those connected to the AUDIO\_TS are prepared for the DVD-Audio and DVD-Audio player.

Generally, each of the DVD-Video and DVD-Audio contains both VIDEO\_TS and AUDIO\_TS. However, the DVD-Video has the AUDIO\_TS emptied (all of the information on the data stored in the DVD-Video disk being contained in the VIDEO\_TS) while the DVD-Audio has the AUDIO\_TS containing the information on the positions of the audio titles recorded on the disk and the VIDEO\_TS also containing the information on the positions of the titles of reproducible information (spec: e.g., sampling frequency) in the DVD-Video player. Hence, if a DVD has no effective data in the AUDIO\_TS, it is determined as being DVD-Video, or otherwise, i.e., if the DVD player detects effective data in the AUDIO\_TS, it determines the disk as being DVD-Audio. Namely, the DVD player detects the AUDIO\_TS of a DVD to distinguish DVD-Video and DVD-Audio.

The logical data structure of DVD-Video is illustrated in FIG. 1. The concept of the logical data structure of DVD-Video includes structure of a volume space, structure of a video manager (VMG), structure of a video title set (VTS), and structure of a video object set (VOBS).

Describing the logical data structure of the volume space, with reference to FIG. 2, it includes the volume and file structure, single DVD-Video zone and DVD others zone. The DVD-Video zone, which shall be assigned for the data structure of the DVD-Video, includes a single VMG and VTSS numbering from at least 1 to a maximum of 99. The VMG is allocated at the leading part of the DVD-Video zone. Each VTS includes between 3 and 12 files.

Referring to FIG. 3 for illustrating the VMG and VTS structure, all VOBs are recorded in contiguous blocks. Each VOB



includes video, audio and sub-picture data. The VMG includes a video manager information file (VMGI) as control data, video manager menu file of the VOBS (VMGM\_VOBS) and VGMI backup file. Each VTS includes VTSI as control data, a video title set menu of VOBS (VTSM\_VOBS), a video title set title of VOBS (VTSTT\_VOBS) and a VTSI backup file. The VTSTT\_VOBS includes a plurality of cells (C\_IDN). In the drawing, C\_IDN# indicates cell ID number within a VOBS, and VOB\_IDN# VOB ID number within a VOBS.

Referring to FIG. 4, the VMGI describes information on the related VIDEO\_TS directory. The VMGI starts with a video manager information management table (VMGI\_MAT), followed by a title search pointer table (TT\_SRPT), followed by a video manager menu PGCi unit table (VMGM\_PGCi\_UT), followed by a parental management information table (PTL\_MAIT), followed by a video title set attribute table (VTS\_ATTRT), followed by a text data manager (TXTDT\_MG), followed by a video manager menu cell address table (VMGM\_C\_ADT), followed by a video manager menu video object unit address map (VMGM\_VOBU\_ADMAP).

Referring to FIG. 5 for describing search information of a video title under the VIDEO\_TS directory, the TT\_SRPT starts with TT\_SRPT information (TT\_SRPTI) followed by title search pointers (TT\_SRPs) for every title under the VIDEO\_TS directory. The title number # ranges from 1 to 99.

Referring to FIG. 6, the VTSI provides information for one or more video titles and the video title set menu (VTSM). The VTSI describes the management information of these titles such as the information to search the part\_of title (PTT) and the information to play back the video object set (VOBS), and the video title set menu (VTSM), as well as the information on the attribute of the VOBS.

The VTSI starts with a video title set information management table (VTSI\_MAT), followed by a video title set part\_of\_title search pointer table (VTS\_PTT\_SPRT), followed by a video title set program chain information table (VTS\_PGCIT), followed by a video title set menu PGCi unit table

(VTSM\_PGCI\_UT), followed by a video title set time map table (VTS\_TMAPT), followed by a video title set menu cell address table (VTSM\_C\_ADT), followed by a video title set menu video object unit address map (VTSM\_VOBU\_ADMAP), followed by a video title set cell address table (VTS\_C\_ADT), followed by a video title set video object unit address map (VTS\_VOBU\_ADMAP) as shown in FIG. 6.

Referring to FIG. 7, the VTSM\_MAT describes the start address of each piece of information in the VTSI and the attribute of the VOBS in the VTS. In this VTSM\_MAT, the audio stream attribute table of the VTS (VTS\_AST\_ATRT) of RBP 516 to 579 stores 8 VTS\_AST\_ATRs #0 to #7 as shown in FIG. 8A. Each VTS\_AST\_ATR includes 8 bytes arranged as shown in FIG. 8B. Each field value represents the internal information of the audio stream of the VTSM\_VOBS. Describing the contents of one VTS\_AST\_ATR with reference to FIG. 8B, the audio coding mode of b63 to b61 is as shown in the following Table 1:

Table 1

b63-b61	Audio Coding Mode
000b	Dolby AC-3
010b	MPEG-1 or MPEG-2 without extension bit stream
011b	MPEG-2 with extension bitstream
100b	Linear PCM audio
110b	DTS (option)
111b	SDDS (option)
Others	reserved

The multichannel extension of b60 is to store information on whether the multichannel extension is made or not. Namely, 0b

represents the multichannel extension not selected while 1b represents the multichannel extension selected according to the information of the VTS\_MU\_AST\_ATRT recorded in RBP 792 to 983 of the VTSI\_MAT shown in FIG. 7.

5           The audio type of b59 to b58 is as shown in Table 2.

Table 2

	b59-b58	audio type
10	00b	Not specified
	01b	Language included
15	others	reserved

The audio application mode of b57 to b56 is as shown in the following Table 3.

Table 3

20	b57-b56	audio application mode
	00b	Not specified
	01b	Karaoke mode
25	10b	Surround mode
	11b	reserved

30           For the quantization /DRC of b55 to b54, when the audio coding mode is '000b', '11b' is recorded. When the audio coding mode is '010b' or '011b', the quantization / DRC is defined as:  
00b: Dynamic range control data do not exist in MPEG audio stream

01b: Dynamic range control data exist in MPEG audio stream

10b: reserved

11b: reserved

When the audio coding mode '100b', then the quantization /  
DRC is defined as in the following Table 4.

Table 4

b55-b54	Quantization DRC
00b	16bits
01b	20bits
10b	24bits
11b	reserved

The sampling frequency  $f_s$  of b53 to b52 is as shown in Table 5.

Table 5

b53-b52	$f_s$
00b	48KHz
01b	96KHz
10b	reserved
11b	reserved

The number of audio channels stored in b50 to b48 is as shown in Table 6.

Table 6

	b50-b48	No. of Audio Channels
5	000b	1ch (mono)
	001b	2ch (stereo)
10	010b	3ch (multichannel)
	011b	4ch (multichannel)
	100b	5ch (multichannel)
15	101b	6ch (multichannel)
	110b	7ch (multichannel)
20	111b	8ch (multichannel)
	others	reserved

In addition, the multichannel audio stream attribute table of the VTS of RBP 792 to 983 in the VTSI\_MAT of FIG. 7 provides the VTS\_MU\_AST\_ATRs #0 to #7 of 8 audio streams as shown in FIG. 9A. Each VTS\_MU\_AST\_ATR includes a VTS\_MU\_AST\_ATR (1) of 8 bytes as shown in FIG. 9B and a VTS\_MU\_AST\_ATR (2) of 16 bytes as shown in FIGS. 9C and 9D.

Thus, the information zone VIDEO\_TS of the DVD-Video is constructed as shown in FIGS. 2 to 9D. Such a DVD-Video stores both video and audio data, and therefore can not provide audio data of good quality. Hence, it is impossible to record the audio data on a DVD-Video at the maximum rate 10.08Mbps of the DVD. Namely, the maximum bit rate to record the audio data on the DVD-Video is 6.75Mbps, and the maximum sampling frequency

96KHz. The linear PCM multichannel audio data recorded on the DVD-Video is as shown in Table 7.

Table 7

5	fs	Qb	Maximum Number of Channels	Maximum Bit Rate
	48KHz	16bit	8ch	6.144Mbps
10	48KHz	20bit	6ch	5.760Mbps
	48KHz	24bit	5ch	5.760Mbps
15	96KHz	16bit	4ch	6.144Mbps
	96KHz	20bit	3ch	5.760Mbps
20	96KHz	24bit	2ch	4.608Mbps

The present invention is to provide a DVD-Audio for recording only audio data not including video data. Hence, the DVD-Audio can store multichannel audio data in the range of the maximum bit rate 10.08Mbps of the DVD, which is different from the DVD-Video. Thus, the DVD-Audio may use the sampling frequency of at most 192KHz, and extend the number of the audio channels to 13.

The file structure stored in the information zone of the DVD-Audio is essentially the same as shown in FIG. 1. The files included in the AUDIO\_TS directory are to provide for the DVD-Audio and its player. Hence, the DVD-Audio has both AUDIO\_TS and VIDEO\_TS, where the VIDEO\_TS stores the positional information of the VMG and titles which are reproducible in a DVD-Video player. The AUDIO\_TS stores the positional information of the AMG and

titles which are reproducible in a DVD-Audio player. The DVD player determines whether an inserted DVD is DVD-Audio or not by checking the contents of the audio title set directory AUDIO\_TS.

Referring to FIG. 10, the logical data structure of the DVD-Audio includes structure of a volume space, structure of an audio manager (AMG), structure of an audio title set (ATS), and structure of an audio object set (AOBS). The volume space includes the volume and file structure, a single DVD-Audio zone and DVD others zone. The DVD-Audio zone, which is assigned for the data structure of the DVD-Audio, includes a single AMG and VTSS numbering from at least 1 to a maximum of 99. The AMG is allocated at the leading part of the DVD-Audio zone, including 2 or 3 files. Each VTS includes between 3 and 12 files.

The AMG and ATS are structured similar to the VMG and VTS of the DVD-Video, as shown in FIGS. 11-17C. However, the data structure for the linear PCM and pseudo-lossless psychoacoustic coded data (PLPCD) of the DVD-Audio is not proper for processing the linear PCM, lossless coded data or PLPCD according to the new sampling frequency of the DVD-Audio. Therefore, the data structures of the AMG and ATS are made somewhat different from that of the VMG and VTS. Namely, the part allocated for the sampling frequency and channel number in the part allocated for the audio attribute of the VMG and VTS is extended for the AMG and ATS.

Referring to FIG. 11 for illustrating the AMG and ATS structures, all AOBs are recorded in contiguous blocks. The AMG includes an audio manager information file (AMGI) as control data, an audio manager menu file of the AOBs (AMGM\_AOBS) and an AGMI backup file. Each ATS includes ATSI as control data, an audio title set menu of AOBs (ATSM\_AOBS), an audio title set title of AOBs (ATSTT\_AOBS) and an ATSI backup file. The ATSTT\_AOBS includes a plurality of cells (C\_IDN). In the drawing, C\_IDN# indicates cell ID number within an AOBs, and AOB\_IDN# AOB ID number within an AOBs.

Referring to FIG. 12, the AMGI describes information on the related AUDIO\_TS directory. The AMGI starts with an audio manager information management table (AMGI\_MAT), followed by a title search pointer table (TT\_SRPT), followed by an audio manager menu PGCi unit table (AMGM\_PGCi\_UT), followed by a parental management information table (PTL\_MAIT), followed by an audio title set attribute table (ATS\_ATRT), followed by a text data manager (TXTDT\_MG), followed by an audio manager menu cell address table (AMGM\_C\_ADT), followed by an audio manager menu audio object unit address map (AMGM\_AOBU\_ADMAP).

Referring to FIG. 13 for describing search information of an audio title under the VIDEO\_TS directory, the TT\_SRPT starts with TT\_SRPT information (TT\_SRPTI) followed by title search pointers (TT\_SRP) for every title under the AUDIO\_TS directory. The title number # ranges from 1 to 99.

Referring to FIG. 14, the ATSI provides information for one or more audio titles and audio title set menu (ATSM). The ATSI describes the management information of these titles such as the information to search the part\_of title (PTT) and the information to play back the audio object set (AOBS), and the audio title set menu (ATSM), as well as the information on the attribute of the AOBS.

The ATSI starts with audio title set information management table (ATSI\_MAT), followed by an audio title set part\_of\_title search pointer table (ATS\_PTT\_SPRT), followed by an audio title set program chain information table (ATS\_PGCIT), followed by an audio title set menu PGCi unit table (ATSM\_PGCi\_UT), followed by an audio title set time map table (ATS\_TMAPT), followed by an audio title set menu cell address table (ATSM\_C\_ADT), followed by an audio title set menu audio object unit address map (ATSM\_AOBU\_ADMAP), followed by an audio title set cell address table (ATS\_C\_ADT), followed by an audio title set audio object unit address map (ATS\_AOBU\_ADMAP) as shown in FIG. 14.

Referring to FIG. 15, the ATSI\_MAT describes the start address of each information in the ATSI and the attribute of the



AOBS in the ATS. The ATSI\_MAT is provided with ATSM\_AST\_ATR of RBP 260 to 267, ATS\_AST\_ATRT of RBP 516 to 579 and ATS\_MU\_AST\_ATR\_EXT of RBP 792 to 1298.

The audio coding mode of the ATSM\_AST\_ATR and ATS\_AST\_ATRT stores the coding information of the audio data recorded in the DVD-Audio. The present embodiment describes the recording on the DVD-Audio of the audio data of lossless psychoacoustic coding and pseudo-lossless psychoacoustic coding (hereinafter referred to as "psychoacoustic coding"). In addition, it is assumed that the psychoacoustic coding mode is performed with a DTS coding system, which may support the lossless psychoacoustic coding and pseudo-lossless psychoacoustic coding. In this case, the DTS coding mode is optional, and if b63 to b61 is '110b', the DTS audio coding mode is selected.

For the change of ATSM\_AST\_ATR, the data pattern and definition of b55 to b48 are changed. Namely, the sampling frequency data of b53 to b52 is changed, and the reserved bit of b51 is included in the audio channels, as shown in FIG. 16. Thus, the audio sampling frequency  $f_s$  is changed as shown in Table 8.

Table 8

b53-b52	b51	$f_s$
00b	0	48KHz
01b	0	96KHz
10b	0	192KHz
11b	0	reserved
00b	1	44.1KHz
01b	1	88.2KHz
10b	1	176.4KHz
11b	1	reserved

In addition, the number of the audio channels is changed as shown in Tables 9a and 9b.

Table 9a

5	b51-b48	Number of Audio Channels
	0000b	1ch (mono)
	0001b	2ch (stereo)
10	0010b	3ch (multichannel)
	0011b	4ch (multichannel)
15	0100b	5ch (multichannel)
	0101b	6ch (multichannel)
	0110b	7ch (multichannel)
20	0111b	8ch (multichannel)
	1000b	9ch (multichannel)
25	1001b	10ch (multichannel)
	1010b	11ch (multichannel)
30	1011b	12ch (multichannel)

Table 9b

	1100b	13ch (multichannel)
5	1101b	14ch (multichannel)
	1110b	15ch (multichannel)
10	1111b	16ch (multichannel)

The ATS\_AST\_ATRT of RBP 516 to 579 in the ATSI\_MAT as shown in FIG. 15 stores ATS\_AST\_ATRs of 8 audio streams #0 to #7 as shown in FIG. 17A, each of which includes 8 bytes structured as shown in FIG. 17B, and each field value serves as the internal information of the audio stream of the ATSM\_AOBS.

The data pattern and definition of b55 to b48 are changed as shown in FIG. 17B. Namely, in b55 to b48 of the VTS\_AST\_ATRT as shown in FIG. 8B, the reserved bit of b51 is included in the audio channels. Consequently, the audio sampling frequency fs is changed as shown in Table 8 while the number of the audio channels is changed as shown in Tables 9a and 9b.

In the ATS\_MU\_AST\_ATRT, the information as shown in FIGS. 18B and 18C are added to the information of FIGS. 9B and 9C. The ATS\_MU\_AST\_ATR(1) and ATS\_MU\_AST\_ATR(2) provide the information on the audio data and channel mixing coefficients up to 8 channels, and therefore can not provide the information on the linear PCM audio over 8 channels. The present invention may provide up to 13 channels, so that the information from the 9th channel to the 13th channel are recorded in the reserved regions after the ATS\_MU\_AST\_ATR(1) and ATS\_MU\_AST\_ATR(2). Referring to FIG. 18A, the ATS\_MU\_AST\_ATRT provides 13 ATS\_MU\_AST\_ATRs #0 to #12 each having 39 bytes to store the information on 13 audio channels and the mixing coefficients.

Each ATS\_MU\_AST\_ATR includes the audio channel information as shown in FIG. 18B and the mixing coefficient information as

shown in FIG. 18C. FIG. 18B illustrates only the information of the extended five audio channels `ATS_MU_AST_ATR_EXT(1)`, while omitting the `ATS_MU_AST_ATR(1)` for storing the data information of the 8 audio channels. Likewise, FIG. 18C illustrates only the information of the extended five audio channels `ATS_MU_AST_ATR_EXT(2)`, while omitting the `ATS_MU_AST_ATR(2)` for storing the data information of the 8 audio channels.

The `ATSI_MAT` represents the information on the audio data recorded on the DVD-Audio, forming the first part of each audio title and followed by the AOBS of substantial audio data. Of course, the `VTSI_MAT` as shown in FIG. 7 represent also the information on the video data, sub-picture data and audio data recorded on the DVD-Video, forming the first part of each video title and followed by the VOBS of substantial data. The AOBS is structured as shown in FIG. 19, providing a plurality of audio packs to store the audio data. Likewise, the VOBS is structured similar to FIG. 19, providing a plurality of video packs, sub-picture packs and audio packs to respectively store the video data, sub-picture data and audio data.

The structure of the AOBS is similar to that of the VOBS, and therefore description of the structure of the VOBS will help understand the structure of the AOBS. The VOBS includes a plurality of video objects `VOB_IDN1` to `VOB_IDNi`, each of which in turn includes a plurality of cells `C_IDN1` to `C_IDNj`, each of which in turn includes a plurality of video object units `VOBUs`, each of which in turn includes a plurality of video packs.

The video data recorded in a DVD-Video includes a plurality of packs, whose structure is illustrated in FIG. 20 without a padding packet. Referring to FIG. 20, one pack has a size of 2048 bytes including a pack header of 14 bytes and a plurality of packets for video, audio, sub-picture, DSI or PCI of 2034 bytes. Further, the packet header includes a pack start code of 4 bytes, SCR of 6 bytes, `program_mux_rate` of 3 bytes and `stuffing_length` of 1 byte.

Referring to FIG. 21A, the linear PCM audio pack includes a pack header of 14 bytes and a linear audio packet of 2034 bytes. The audio packet includes a packet header of 1 byte, sub\_stream\_id of 1 byte, audio frame information of 3 bytes and linear PCM audio data of 1 to 2013 bytes.

Referring to FIG. 21B, the dolby AC-3 audio pack includes a pack header of 14 bytes and a dolby AC-3 audio packet of 2034 bytes. The audio packet further includes a packet header of 1 byte, sub\_stream\_id of 1 byte, audio frame information of 3 bytes and AC-3 audio data of 1 to 2016 bytes.

FIG. 21C illustrates the structure of an MPEG-1 or MPEG-2 audio pack without an extension bit stream, and FIG. 21D the structure of MPEG-2 with an extension stream. The structures of the audio packs as shown in Figs 21A to 21D are shown in Table 10, additionally provided with private data areas corresponding to their formats.

Table 10

Field	Bit	Byte	Value	Comment
packet_start_code_prefix	24	3	00 0001h	
stream_id	8	1	1011 1101b	private_ stream_1
PES_packet_length	16	2		
'10'	2	3		
PES_scrambling_control	2	3	00b	not

					scrambled
5	PES_priority	1	3	0	no priority
10	data_alignment_indicator	1	3	0	not defined by descriptor
15	copyright	1	3	0	not defined by descriptor
	original_or_copy	1	3	1 or 0	original:1 copy:0
20	PTS_DTS_flags	2	3	10 or 00b	
25	ESCR_flag	1	3	0	no ESCR field
30	ES_rate_flag	1	3	0	no EST rate field
	DSTM_trick_mode_flag	1	3	0	no trick mode field
35					no copy

	additional_copy_info_flag	1	3	0	info field
5	PES_CRC_flag	1	3	0	no CRC field
	PES_extension_flag	1	3	0 or 1	
10	PES_header_data_length	8	3	0 to 15	
	'0010'	4	5	provider defined	Note 1
15	PTS[32...30]	3	5	provider defined	Note 1
	marker_bit	1	5	provider defined	Note 1
20	PTS[29...15]	15	5	provider defined	Note 1
	marker_bit	1	5	provider defined	Note 1
25	PTS[14...0]	15	5	provider defined	Note 1
	marker_bit	1	5	provider defined	Note 1
30	PES_private_data_flag	1	1	0	Note 2
35	pack_header_field_flag	1	1	0	Note 2

	program_packet_sequence_	1	1	0	Note 2
	counter_flag				
5	P_STD_buffer_flag	1	1	1	Note 2
	reserved	3	1	111b	Note 2
	PES_extension_flag_2	1	1	0	Note 2
10	'01'	2	2	01b	Note 2
	P_STD_buffer_scale	1	2	1	Note 2
15	P_STD_buffer_size	13	2	58	Note 2
	stuffing_byte	-	0-7		

In Table 10, Notes 1 and 2 are described as follows:

20 Note 1: "PTS[32...0]" shall be described in every audio packet in which the first sample of an audio frame is included.

Note 2: These fields occur in the first audio packet of each VOB, and are prohibited in the subsequent audio packets.



Table 11

	Field	Bit	Byte	Value	Comment
5	sub_stream_id	8	1	10100***b	Note 1
	number_of_frame_headers	8			Note 2
	first_access_unit_pointer	16		Provider	Note 3
10				Defined	
	audio_emphasis_flag	1			Note 4
	audio_mute_flag	1			Note 5
			3		
15	reserved	1		0	
	audio_frame_number	5			Note 6
				Provider	
	quantization_word_length	2		Defined	Note 7
20					
	audio sampling frequency	2			Note 8
	reserved	1		0	
	number_of_audio_channels	3		Provider	Note 9
25			3	Defined	
	dynamic_range_control	8			Note 10
30	Audio Data Area (Linear PCM)				

In Table 11, Notes 1 to 10 are described as follows:

Note 1: \*\*\* represents decoding an audio data stream number.

Note 2: "number\_of\_frame\_headers" describes the number of audio frames whose first byte is in this audio packet.

Note 3: The access unit is the audio frame. The first access unit is the first audio frame which has the first byte of the audio frame.

Note 4: "audio\_emphasis\_flag" describes the state of emphasis. When "audio\_sampling\_frequency" is 96KHz, "emphasis off" is described in this field. The emphasis is applied to all audio samples decoded from the first access unit.

0b: emphasis off

1b: emphasis on

Note 5: "audio\_mute\_flag" describes the state of mute while all data in the audio frame is ZERO. The mute is applied to all audio samples decoded from the first access unit.

Note 6: "audio\_frame\_number" describes the frame number of the first access unit in the Group of audio frame (GOF) with the numbers between '0' and '19'.

Note 7: "quantization\_word\_length" describes the word-length which the audio samples are quantized to.

00b: 16 bits

01b: 20 bits

10b: 24 bits

11b: reserved

Note 8: "audio\_sampling\_frequency" describes the sampling frequency of the audio sample.

00b: 48KHz

01b: 96KHz

Others: reserved

Note 9: "number\_of\_channels" describes the number of audio channels.

000b: 1ch (mono)

001b: 2ch (stereo)

010b: 3ch

011b: 4ch

100b: 5ch (multichannel)

101b: 6ch

110b: 7ch

111b: 8ch

Note 10: "dynamic\_range\_control" describes the dynamic word control word to compress the dynamic range from the first access unit.

In the audio packets as shown in FIGS. 21A to 21D, the stream\_id of the linear PCM audio packet is 1011 1101b (private\_stream\_1), and the sub\_stream\_id 1010 0\*\*\*b. The stream\_id of the AC-3 audio packet is 1011 1101b (private\_stream\_1), and the sub\_stream\_id 1000 0\*\*\*b. The stream\_id of the MPEG audio packet is 1100 0\*\*\*b or 1101 0\*\*\*b, and no sub\_stream\_id. "\*\*\*\*" in the stream\_id or sub\_stream\_id indicates the decoding audio stream number which has a value between "0" and "7", and the decoding audio stream numbers are not assigned the same number regardless of the audio compression mode.

FIG. 22 illustrates the structure of the audio stream and packs. The audio data used in the DVD-Audio may include linear PCM data, dolby AC-3 data and MPEG audio data. The audio stream further includes a plurality of audio packs. In addition, each audio pack constitutes a unit of 2048 bytes as shown in FIG. 22. In this case, the form of encoding the linear PCM audio is based on Table 12.

Table 12

Sampling frequency(fs)	48KHz	96KHz
Sampling Phase	Shall be simultaneous for all channels in a stream	
Quantization	16 bits or more, 2's complementary code	
Emphasis	Can be applied (zero point: 50μs, pole: 15μs)	Can not be applied

In Table 12, the audio stream data for linear PCM includes contiguous GOFs (Group of Audio Frames), each of which includes 20 audio frames except for the last GOF. The last GOF includes no more than 20 audio frames.

FIG. 23 illustrates the structure of the audio frame. One audio frame includes sample data which correspond to the presentation time of 1/600 second. One audio frame contains 80 or 160 audio sample data according to a frequency (fs) of 48KHz or 96KHz. One GOF corresponds to the presentation time of 1/30 second.

FIGS. 24A to 24C illustrate a sample data alignment for linear PCM. Sample data is formed by the data from each channel sampled out at the same time. Therefore, the size of sample data varies with the audio stream attribute. The sampled data is continuously arranged. Two sample data for each mode are shown in FIGS. 24A to 24C. FIG. 24A illustrates a 16 bits mode, FIG. 24B illustrates a 20 bits mode and FIG. 24C illustrates a 24 bits mode. The packet data structure of the linear PCM audio is as shown in Table 13.

Table 13

Stream Mode			Data in a Packet			
Number of Channels	fs (KHz)	Quantization	Maximum number of samples in a packet	Data size (byte)	Packet Stuffing of first/other PES packet (byte)	Padding for first/other PES packet (byte)
2	48/96	16	1004	2008	2/5	0/0

	1						
	mono	48/96	20	804	2010	0/3	0/0
5		48/96	24	670	2010	0/3	0/0
		48/96	16	502	2008	2/5	0/0
	2						
	stereo	48/96	20	402	2010	0/3	0/0
10		48/96	24	334	2004	6/0	0/9
		48/96	16	334	2004	6/0	0/9
15	3	48/96	20	268	2010	0/3	0/0
		48	24	222	1988	0/0	12/15
		48/96	16	250	2000	0/0	10/13
	4	48	20	200	2000	0/0	10/13
20		48	24	166	1992	0/0	18/21
		48	16	200	2000	0/0	10/13
25	5	48	20	160	2000	0/0	10/13
		48	24	134	2010	0/3	0/0
30		48	16	166	1992	0/0	18/21
	6	48	20	134	2010	0/3	0/0
35	7	48	16	142	1988	0/0	22/25
	8	48	16	124	1984	0/0	26/29

If the number of samples is less than in Table 13, the length of a padding packet may increase to adjust the pack size. Samples shall be aligned at packet boundary. Namely, the audio sample data of every audio packet for linear PCM audio always start with the first byte of  $S_{2n}$  described in Table 13. The channel assignment for linear PCM is as follows:

In the stereo presentation mode, the descriptions of channels, ACH0 and ACH1 correspond to left channel (L-ch) and right channel (R-ch) respectively. Multichannel coding is required to keep compatibility with the stereo mode.

The structure of the DVD-Audio is as shown in FIG. 19. Since the DVD-Audio is to store audio data, it contains no video pack (V\_PCK) or sub-picture pack (SP\_PCK), or otherwise only small amounts of them. The AOBS includes a plurality of packs of data as the VOBS does. The general structure of the audio pack is as shown in FIGS. 20 and 21A to 21D. It is assumed that the inventive DVD-Audio does not employ MPEG and AC-3 and instead records audio data of linear PCM and compression coding system.

Tables 10 and 11 illustrate the linear PCM audio packet of the DVD-Video, which may be altered to obtain the linear PCM audio packet of the DVD-Audio. Describing the linear PCM system of the DVD-Audio, the sampling frequencies are 48, 44.1, 96, 188.2, 192 or 176.4KHz, the number of quantization bits is 16, 20 or 24 bits, and the number of audio channels is from 1ch to the maximum allowed by the bit rate. The number of the audio channels may be determined by Eq. 1.

Eq. 1

$$N = \frac{Mby}{Fs * Qb}$$

Fs: Sampling Frequency(Hz) -> 48KHz, 44.1KHz, 96KHz, 88.2KHz, 192KHz, or 176.4KHz

Qb: Number of Quantization Bits -> 16bits, 20bits, or 24bits

Mby: Maximum Data Transfer Rate of DVD(Mbps) -> 10.08Mbps

N: Maximum Number of Possible Channels Determined by Data Transmission Rate, Sampling Frequency and Number of Quantization Bits of DVD.

The number of channels determined by Eq. 1 is shown in Table 14.

Table 14

Sampling Frequency	Number of Quantization Bits	Maximum Number of Channels
48KHz/44.1KHz	16 bits	8
48KHz/44.1KHz	20	8
48KHz/44.1KHz	24	8
96KHz/88.2KHz	16	6
96KHz/88.2KHz	20	5
96KHz/88.2KHz	24	4
192KHz/176.4KHz	16	3
192KHz/176.4KHz	20	2
192KHz/176.4KHz	24	2

The structure of the linear PCM audio pack of the DVD-Audio is constructed as shown in FIG. 25, which is the same as that of the DVD-Video as shown in FIG. 21A. Namely, one audio pack comprises a pack header of 14 bytes and one or more linear PCM packets of at maximum 2021 bytes. The pack header is based on an MPEG2 system layer.

The structure of the linear PCM audio packet is also based on the MPEG2 system layer. The linear PCM audio packet is constructed as shown in Tables 15 and 16. Table 15 has the same

structure as Table 10 while Table 16 for representing private data structure has a structure different from that of Table 11.

Table 15

5	Field	Bit	Byte	Value	Comment
	packet_start_code_prefix	24	3	00 0001h	
10	stream_id	8	1	1011 1101b	private_ stream_1
	PES_packet_length	16	2		
15	'10'	2	3		
20	PES_scrambling_control	2	3	00b	not scrambled
25	PES_priority	1	3	0	no priority
	data_alignment_indicator	1	3	0	not defined by descriptor
30	copyright	1	3	0	not defined by descriptor



	original_or_copy	1	3	1 or 0	original:1 copy:0
5	PTS_DTS_flags	2	3	10 or 00b	
10	ESCR_flag	1	3	0	no ESCR field
15	ES_rate_flag	1	3	0	no EST rate field
20	DSTM_trick_mode_flag	1	3	0	no trick mode field
25	additional_copy_info_ flag	1	3	0	no copy info field
30	PES_CRC_flag	1	3	0	no CRC field
	PES_extension_flag	1	3	0 or 1	
	PES_header_data_length	8	3	0 to 15	
35	'0010'	4	5	provider defined	Note 1

	PTS[32...30]	3	5	provider defined	Note 1
5	marker_bit	1	5	provider defined	Note 1
	PTS[29...15]	15	5	provider defined	Note 1
10	marker_bit	1	5	provider defined	Note 1
	PTS[14...0]	15	5	provider defined	Note 1
15	marker_bit	1	5	provider defined	Note 1
20	PES_private_data_flag	1	1	0	Note 2
	pack_header_field_flag	1	1	0	Note 2
25	program_packet_sequence_counter_flag	1	1	0	Note 2
	P_STD_buffer_flag	1	1	1	Note 2
30	reserved	3	1	111b	Note 2
	PES_extension_flag_2	1	1	0	Note 2
35	'01'	2	2	01b	Note 2
	P_STD_buffer_scale	1	2	1	Note 2

P_STD_buffer_size	13	2	58	Note 2
stuffing_byte	-	0-7		

5 Table 16

	Field	Bit	Byte	Value	Comment
	sub_stream-id	8	1	10100***b	Note 1
	number_of_frame_headers	8	3	Provider Defined	Note 2
	first_access_unit_pointer	16		Provider Defined	Note 3
10	audio_emphasis_flag	1		Provider Defined	Note 4
	audio_mute_flag	1		Provider Defined	Note 5
	reserved	1		0	
	audio_frame_number	5		Provider Defined	Note 6
	quantization_word_length	2		Provider Defined	Note 7
15	audio_sampling_frequency	3		Provider Defined	Note 8
	number_of_audio_channels	3		Provider Defined	Note 9
	dynamic_range_control	8		Provider Defined	Note 10
Audio Data Area (Linear PCM)					

In Table 16, Notes 1 to 10 are described as follows:

Note 1: \*\*\* represents decoding the audio data stream number.

5        Note 2: "number\_of\_frame\_headers" describes the number of audio frames whose first byte is in this audio packet.

Note 3: The access unit is the audio frame. The first access unit is the first audio frame which has the first byte of the audio frame.

10       Note 4: "audio\_emphasis\_flag" describes the state of emphasis. When "audio\_sampling\_frequency" is 96KHz, "emphasis off" is described in this field. The emphasis is applied to all audio samples decoded from the first access unit.

0b: emphasis off

1b: emphasis on

15       Note 5: "audio\_mute\_flag" describes the state of mute while all data in the audio frame is ZERO. The mute is applied to all audio samples decoded from the first access unit.

0b: mute off

1b: mute on

20       Note 6: "audio\_frame\_number" describes the frame number of the first access unit in the Group of audio frame (GOF) with the numbers between '0' and '19'.

Note 7: "quantization\_word\_length" describes the word-length which the audio samples are quantized to.

25       00b: 16 bits

01b: 20 bits

10b: 24 bits

11b: reserved

30       Note 8: "audio\_sampling\_frequency" describes the sampling frequency of the audio sample.

00b: 48KHz

01b: 96KHz

10b: 192KHz

11b: reserved

35       100b: 44.1KHz

101b: 88.2KHz

110b: 176.4KHz

111b: reserved

Note 9: "number\_of\_channels" describes the number of audio channels.

0000b: 1ch (mono)

0001b: 2ch (stereo)

0010b: 3ch

0011b: 4ch

0100b: 5ch

0101b: 6ch (multichannel)

0110b: 7ch

0111b: 8ch

Note 10: "dynamic\_range\_control" describes the dynamic word control word to compress the dynamic range from the first access unit.

The packet data structure of the linear PCM audio and corresponding frame size of 48KHz/192KHz are as shown in Table 17.

Table 17

Stream Mode			Data in a Packet			
Number of Channels	fs (KHz)	Quantization	Maximum number of samples in a packet	Data size (byte)	Packet Stuffing of first/other PES packet (byte)	Padding for first/other PES packet (byte)
	48/96/192	16	1004	2008	2/5	0/0

5	1						
	mono	48/96/192	20	804	2010	0/3	0/0
		48/96/192	24	670	2010	0/3	0/0
		48/96/192	16	502	2008	2/5	0/0
	2						
10	stereo	48/96/192	20	402	2010	0/5	0/0
		48/96/192	24	334	2004	6/0	0/9
		48/96/192	16	334	2004	6/0	0/9
15	3	48/96	20	268	2010	0/3	0/0
		48/96	24	222	1988	0/0	12/15
		48/96	16	250	2000	0/0	10/13
20	4	48/96	20	200	2000	0/0	10/13
		48/96	24	166	1992	0/0	18/21
		48/96	16	200	2000	0/0	10/13
25	5	48/96	20	160	2000	0/0	10/13
		48	24	134	2010	0/3	0/0
		48/96	16	166	1992	0/0	18/21
30	6	48	20	134	2010	0/3	0/0
		48	24	110	1980	0/0	30/33
35							

5	7	48	16	142	1988	0/0	22/25
		48	20	114	1995	0/0	15/18
		48	24	94	1974	0/0	36/39
10	8	48	16	124	1984	0/0	26/29
		48	20	100	2000	0/0	10/13
		48	24	82	1968	0/0	42/45
15	9	48	16	110	1980	0/0	30/33
		48	20	88	1980	0/0	30/33
		48	16	100	2000	0/0	10/13
20	10	48	20	80	2000	0/0	10/13
		48	16	90	1980	0/0	30/33
		48	16	82	1968	0/0	42/45
25	13	48	16	76	1976	0/0	34/37

If the number of samples is less than in Table 17, the length of padding packet may increase to adjust the pack size. Samples shall be aligned at the packet boundary. Namely, the audio sample data of every audio packet starts with the first byte of  $S_{2n}$ . The number of the audio samples in a packet always becomes even.

Thus, in DVD-Audio format, the linear PCM data is processed in frames and GOF. The DVD-Audio may use the sampling frequency

of 192KHz, whereby the basic rule of linear PCM coding may be set as shown in Table 18.

Table 18

5	Sampling frequency(fs)	48KHz/44.1KHz	96KHz/88.2KHz	192KHz/176.4KHz
	Sampling Phase	Shall be simultaneous for all channels in all streams		
10	Quantization	16 bits or more, 2's complementary code		
	Emphasis	Can be applied (zero point: 50 $\mu$ s, pole:15 $\mu$ s)	cannot be applied	

One audio frame contains 320 audio sample data when fs is 192KHz. One GOF corresponds to the presentation time of 1/30 second as in the DVD-Video. The sampling frequency of 96KHz is used to achieve multichannel to store quality audio data.

When recording the linear PCM audio data using the sampling frequency of 48KHz and quantization of 16bits, 13 channels are available so as to record the audio data of 10 channels required by the present multichannel music. However, when using the sampling frequency of 192KHz and quantization of 24bits, only 2 channels are available to record audio data, which can not meet the requirement of the multichannel music. Namely, it is impossible to achieve multichannel audio function with high sampling frequency and a great number of data bits. However, such limitation may be resolved by lossless coding or pseudo-lossless coding. The compression ratio of lossless coding is about 2:1 while that of pseudo-lossless psychoacoustic coding is about 4:1.



It is assumed that the inventive DVD-Audio employs DTS (Digital Theater System) coding which is pseudo-lossless psychoacoustic coding with the compression ratio of about 4:1. Further, the DTS makes it possible to perform lossless coding. The DTS can provide a sufficient number of channels without significant degradation of sound quality. For the DTS may carry out coding for a high specification with the sampling frequency of 192KHz and 24bit quantization compared to different compression coding algorithms presently proposed, and has been developed to minimize degradation of sound quality instead of reducing the bit rate. The DTS has the sampling frequencies of 48KHz, 44.1KHz, 96KHz, 88.2KHz, 192KHz or 176.4KHz, the quantization bit number of 16, 20 and 24, and the number of channels from 1ch coding to the maximum allowed by the bit rate. The number of audio channels may be determined by Eq. 2.

$$N = \frac{Mby \cdot Ccy}{Fs \cdot Qb}$$

Fs: Sampling Frequency(Hz) -> 48KHz, 44.1KHz, 96KHz, 88.2KHz, 192KHz, or 176.4KHz

Qb: Number of Quantization Bits -> 16, 20, or 24

Mby: Maximum Data Transfer Rate of DVD(Mbps) -> 10.08Mbps

Ccy: Compression ratio of Pseudo-Lossless Psychoacoustic Coding

N: Maximum Number of Audio Channels Determined by Data Transfer Rate, Sampling Frequency and Number of Quantization Bits of DVD

Assuming the DTS coding with the compression ratio of 4:1 is used for compression coding, the number of channels determined by Eq. 2 is as shown in Table 19. Therefore, in accordance with Eq. 2, each sampling frequency can support 8 or more channels.

Table 19

Sampling Frequency	Number of Quantization Bits	Maximum Number of Channels
48KHz/44.1KHz	16 bits	52
48KHz/44.1KHz	20	42
48KHz/44.1KHz	24	35
96KHz/88.2KHz	16	26
96KHz/88.2KHz	20	21
96KHz/88.2KHz	24	17
192KHz/176.4KHz	16	13
192KHz/176.4KHz	20	10
192KHz/176.4KHz	24	8

Thus, the inventive DVD-Audio is constructed based on the structure of the MPEG2 system layer, and therefore, the compression coded audio pack structure comprises a pack header of 14 bytes and compression coded audio packets each having a maximum 2021 bytes, as shown in FIG. 26. The pack header meets the specification of MPEG2 system layer.

The structure of the compression coded audio packet is also based on the specification of MPEG2 system layer. The compression coded audio packet is constructed as shown in Tables 20 and 21. The Table 20 has the same structure as Table 10 presenting the structure of linear PCM audio packet of the DVD-Video.

Table 20

	Field	Bit	Byte	Value	Comment
5	packet_start_code_prefix	24	3	00 0001h	
	stream_id	8	1	1011 1101b	private_ stream_1
10	PES_packet_length	16	2		
	'10'	2	3		
15	PES_scrambling_control	2	3	00b	not scrambled
20	PES_priority	1	3	0	no priority
25	data_alignment_indicator	1	3	0	not defined by descriptor
30	copyright	1	3	0	not defined by descriptor
	original_or_copy	1	3	1 or 0	original:1 copy:0
35					

	PTS_DTS_flags	2	3	10 or 00b	
5					
	ESCR_flag	1	3	0	no ESCR field
10	ES_rate_flag	1	3	0	no EST rate field
15	DSTM_trick_mode_flag	1	3	0	no trick mode field
	additional_copy_info_ flag	1	3	0	no copy info field
20					
	PES_CRC_flag	1	3	0	no CRC field
25	PES_extension_flag	1	3	0 or 1	
	PES_header_data_length	8	3	0 to 15	
30	'0010'	4	5	provider defined	Note 1
	PTS[32...30]	3	5	provider defined	Note 1
35					

	marker_bit	1	5	provider	Note 1
				defined	
5	PTS[29...15]	15	5	provider	Note 1
				defined	
	marker_bit	1	5	provider	Note 1
				defined	
10	PTS[14...0]	15	5	provider	Note 1
				defined	
	marker_bit	1	5	provider	Note 1
				defined	
15	PES_private_data_flag	1	1	0	Note 2
	pack_header_field_flag	1	1	0	Note 2
20	program_packet_sequence_	1	1	0	Note 2
	counter_flag				
	P_STD_buffer_flag	1	1	1	Note 2
25	reserved	3	1	111b	Note 2
	PES_extension_flag_2	1	1	0	Note 2
30	'01'	2	2	01b	Note 2
	P_STD_buffer_scale	1	2	1	Note 2
	P_STD_buffer_size	13	2	58	Note 2
35	stuffing_byte	-	0-7		

Table 21

	Field	Bit	Byte	Value	Comment
5	sub_stream_id	8	1	&&&& &***b	Note 1
	number_of_frame_headers	8	1	Provider Defined	Note 2
10	first_access_unit_pointer	16	2	Provider Defined	Note 3
DTS Audio data area					

15 In Table 21, Notes 1 to 3 are described as follows:

Note 1: "sub\_stream\_id" varies with the compression coding system, and so becomes "1000 1\*\*\*b" with the DTS. "\*\*\*\*" represents decoding the audio data stream number.

20 Note 2: "number\_of\_frame\_headers" describes the number of audio frames whose first byte is in this audio packet.

Note 3: The access unit is the audio frame. The first\_access\_unit is the first audio frame which has the first byte of the audio frame.

25 Thus, the DVD-Audio is provided with more than 8 channels to perform the compression coding, available sampling frequencies of 48KHz, 44.1KHz, 96KHz, 88.2KHz, 192KHz or 176.4KHz, quantization bit number of 16, 20 or 24, compression ratio from 1:1 to over 5:1, down mixing, dynamic range control and time stamp.

30 The DTS compression algorithm used in the present embodiment has a compression ratio low enough to provide significantly improved sound quality, and may optionally be employed in DVD-Video. The DVD-Video has the structures of DTS pack and packet and restricted items for DTS. For the restricted items, the bit rate after compression is limited up to 1.5Mbps and the sampling frequency for compressible data is only 48KHz. However, in the

35

inventive DVD-Audio employing the DTS algorithm, the sampling frequency is extended to 192KHz, quantization bit number to 24bits, multichannel data compressed to about 4:1, thereby providing desirable sound quality. Namely, the compression coding used in the inventive DVD-Audio employs sampling frequencies of 48KHz/44.1KHz/96KHz/88.2KHz/192KHz/176.4KHz and quantization bit number of 16bits/20bits/24bits so as to compress multichannel linear PCM data by about 4:1 without degrading sound quality.

The DVD-Audio may additionally include VIDEO\_TS and VMG for the information region in a structure which is the same as in the DVD-Video in order to have compatibility with a DVD-Video player. However, the DVD-Video restricts the data transfer rate of an audio stream within 6.144Mbps, as shown in Table 11.

Table 22

	Transfer Rate		Note
	Total Streams	One Stream	
VOB	10.08 Mbps	-	
Video Streams	9.80 Mbps	9.80 Mbps	Number of Streams=1
Audio Streams	9.80 Mbps	6.144 Mbps	Number of Streams=8 (max)
Sub-picture Streams	9.80 Mbps	3.36 Mbps	Number of Streams=32 (max)

Hence, the DVD-Video player may reproduce only the data satisfying the DVD-Video specification among the audio data of the DVD-Audio. The linear PCM data reproduced by the DVD-Video player is as shown in Table 7. Of course, compression coded DTS

data is played by the DVD-Video player to reproduce only DTS streams specified by the DVD-Video. For example, it is assumed that the titles to be stored into a DVD are as shown in Table 23.

Table 23

Sampling Frequency	Number of Quantization Bits	Number of Channels	Remark
48KHz	16	8ch	Title 1
96KHz	16	4ch	Title 2
96KHz	24	2ch	Title 3
96KHz	24	4ch	Title 4
192KHz	24	2ch	Title 5

Then, the VIDEO\_TS and VMG are recorded with the attribute and position information of Titles 1 to 3 but not with the information of Titles 4 and 5. On the contrary, the AUDIO\_TS and AMG of the DVD-Audio are recorded with the information of all the Titles 1 to 5 because the Titles 1 to 3 meet the specifications of both DVD-Video and DVD-Audio but the Titles 4 and 5 only meet the specification of the DVD-Audio. Hence, the Titles 4 and 5 may be played only by the DVD-Audio player. If there is an available space in the data zone, the Titles 4 and 5 may be separately recorded in the available data space with the sampling frequency, quantization bit number and channel number reduced, and the information on the Titles 4 and 5 are stored into the VIDEO\_TS and VMG. Then, the Titles 4 and 5 may be reproduced by a DVD-Video player.



If the compression coding DTS does not meet the specification of the DVD-Video concerning data transfer rate, number of channels, sampling frequency of original data, quantization bit number, etc., the information is recorded only in the AUDIO\_TS and AMG but not in the VIDEO\_TS and VMG. Namely, only the DTS streams satisfying the specification of the DVD-Video may be recorded in the VIDEO\_TS and VMG. In order to reproduce the DTS streams not conforming to the specification of the DVD-Video, they must be coded to meet the transfer rate, number of channels, sampling frequency and quantization bit number specified for the DVD-Video, stored to be recorded in the VIDEO\_TS and VMG.

The AMG and ATSI\_MAT of the DVD-Audio has the same structure as the VMG and VTSI of the DVD-Video. However, the audio data exceeding the specification of the DVD-Video such as sampling frequency of 192KHz and 8 or more channels must be changed to be reproduced by the DVD-Video player. Hence, the disk is made as follows:

When the content of a title to be recorded on the disk is within the specification of the DVD-Video, any one of the VMG and the AMG is kept to make the VIDEO\_TS and AUDIO\_TS direct the file through the VMG or AMG. Then, the DVD-Audio player regards the file as AMG to play while the DVD-Video player regards the file as VMG to play.

Meanwhile, if any of the titles to be recorded in the disk has an audio stream which does not meet the specification of the DVD-Video, both the VMG and the AMG are kept together, and the VMG is not recorded with the information on the titles which do not conform to the specifications of the DVD-Video. Of course, the AMG has not recorded with the information on the titles which have the sampling frequency, number of quantization bits and number of channels altered to be compatible with the DVD-Video player.

However, when the AMG and ATSI\_MAT of the DVD-Audio are structured entirely different from the VMG and VTSI\_MAT of the

DVD-Video, both VMG and AMG must be prepared, and thus both VTSI\_MAT and ATSI\_MAT. Of course, the VMG and VTSI\_MAT are provided with the information on the audio titles conforming to the specification of the DVD-Video.

5       The apparatus for playing the DVD-Audio may be designed independently from the DVD-Video player, but the inventive DVD-Audio player may be combined with the DVD-Video player.

10       Referring to FIG. 27 for illustrating the structure of a DVD-Audio player, a system controller 111 controls the whole operation of the DVD-Audio player, serving the user interface. The system controller 111 determines whether the inserted disk is a DVD-Video or DVD-Audio by checking effective data included in the VIDEO\_TS and AUDIO\_TS directory. When it is checked that effective data exists from the AUDIO\_TS directory, the system  
15       controller 111 determines the inserted disk to be a DVD-Audio and thus, controls its playing operation. But if it is determined that no effective data exists from the AUDIO\_TS, the system controller 111 determines the inserted disk to be a DVD-Video, and thus, stops the playing operation.

20       A pickup device 112 is provided to read the data stored in the DVD-Audio. A servo controller 113 controls the pickup device 112 to perform various servo functions under the control of the system controller 111. A data receiver 114 analyzes and corrects an error occurring in the data output from the pickup device 112,  
25       and includes an error correction circuit. An audio decoder 115 transfers the audio information from the data receiver 114 to the system controller 111, decoding received audio data under the control of the system controller 111.

30       The audio decoder 115 is designed to decode the linear PCM audio data and compression coded audio data according to the present invention, as shown in FIG. 28. Referring to FIG. 28, an input data buffer 211 stores the audio data output from the data receiver 114. A stream selector 212 selectively outputs the audio data stream from the input buffer 211 under the control of  
35       the system controller 111. A linear PCM decoder 213 decodes

linear PCM audio data received from the stream selector 212 to the original audio data. A coding data decoder (Pseudo-Lossless Psychoacoustic Decoding Circuit) 214 decodes compression coded data from the stream selector 212 to the original audio data. An output buffer 215 stores the audio data delivered by the decoding parts 213 and 214. A digital audio formatter 216 converts the audio data from the decoding parts 213 and 214 into a format specified by the system controller 111. The timing controller 210 generates timing control signals to control the operations of the parts of the audio decoder 115 under the control of the system controller 111.

A digital processor (High-bit High-sampling Digital Filter) 116 filters audio data from the audio decoder 115 under the control of the system controller 111. An audio output circuit (High Performance Digital to Analog Converters and Analog Audio Circuitry) 117 converts the audio data from the digital processor 116 into an analog signal.

Referring to FIGS. 27 and 28, the data receiver 114 transfers the audio data reproduced from a DVD-Audio through the pickup device 112 to the audio decoder 115. The reproduced audio data are sequentially stored into the input buffer 211 of the audio decoder 115. The audio data stored in the input buffer 211 are selected by the stream selector 212 and transferred to the decoding parts 213 and 214. Namely, when the system controller 111 demands decoding of the linear PCM audio data, the stream selector 212 transfers the audio data stored in the input buffer 211 to the linear PCM decoder. In addition, when the system controller 111 demands decoding of the compression coded data, the stream selector 212 transfers the audio data stored in the input buffer to the coding data decoder 214.

Describing the decoding operation of the linear PCM audio data, the linear PCM decoder 213 generally performs multichannel downmixing, sampling frequency conversion and requantization of the input signal. For example, when 8-channel data produced from the stream selector 212 is required to be converted into 2-

channel data, the linear PCM decoder 213 performs multichannel downmixing to produce an output of the required channel number. Further, when the input data sampled at 192KHz is required by the system controller 111 to be converted into data sampled at 96KHz, the linear PCM decoder 213 performs the sampling frequency conversion to produce audio data of the required sampling frequency. In addition, when the input audio data of 24 bit quantization is required by the system controller 111 to be converted into data of 16 bit quantization, the linear PCM decoder 213 performs the requantization process to produce audio data of the required number of bits.

Describing the decoding operation of the compression coded audio data, the coding data decoder 214 decodes the compression coded audio data by carrying out the corresponding algorithm under the control of the system controller 111. In this case, the form of the audio data produced from the coding data decoder 214 is specified by the system controller 111. In the present embodiment, the coding data decoder 214 may be a DTS decoder. In addition, the coding data decoder 214 also carries out the multichannel downmixing, sampling frequency conversion and requantization of the input signal together with the algorithm decoding.

The audio data decoded by the decoding parts 213 and 214 is transferred to the output buffer 215 and digital audio formatter 216. The output buffer 215 stores the decoding audio data to synchronize with a control signal supplied by the timing controller 210. The digital audio formatter 216 adjusts the decoded audio data to the transmission format between the digital devices, synchronizing it with a control signal from the timing controller 210. In this case, the output audio data may be delivered to an audio/video system or a computer having the same transmission format.

The decoded audio data from the audio decoder 115 is processed through the digital processor 116 and converted by the audio output circuit 117 into an analog signal. The digital

processor 116 comprises a plurality of digital filters to eliminate noises outside the audio signal band. The digital processor 116 requires a filter coefficient having a much higher resolution and number of taps than the digital filters used in the conventional DVD or CD to process the audio data sampled at 192KHz and quantized by 24 bits. Of course, when a D/A converter of 96KHz and 192KHz becomes commonly available, the digital processor 116 may be included in the D/A converter. The audio output circuit 117 includes a plurality of D/A converters to convert the audio data deprived of noises into an analog audio signal.

Referring to FIG. 29 for illustrating an apparatus for playing both DVD-Video and DVD-Audio, the system controller 311 controls the whole operation of the DVD-Audio/Video player, serving the user interface. The system controller 311 determines whether the inserted disk is a DVD-Video or DVD-Audio by checking effective data included in the VIDEO\_TS and AUDIO\_TS directory. When there is effective data from the AUDIO\_TS directory, the system controller 311 determines the inserted disk to be a DVD-Audio and thus, controls its playing operation. But if there is no effective data from the AUDIO\_TS, the system controller 311 determines the inserted disk to be a DVD-Video, stops the present DVD-Audio playback mode, and changes to the playback mode of the DVD-Video.

A pickup device 312 is provided to read the data stored in the DVD-Audio. A servo controller 313 controls the pickup device 312 to perform various servo functions under the control of the system controller 311. A data receiver 314 analyzes and corrects an error occurring in the data output from the pickup device 312, and includes an error correction circuit. An audio/video decoder 315 transfers the audio information from the data receiver 314 to the system controller 311, decoding received audio data under the control of the system controller 311.

The audio/video decoder 315 is designed to decode video data and audio data, as shown in FIG. 30. Referring to FIG. 30, an input data buffer 411 stores the audio and video data output from

the data receiver 314. A stream parser 412 selectively outputs the audio and video data stream from the input buffer 411 under the control of the system controller 311. An audio decoding circuit 413 decodes the audio data selected by the stream parser 412 in response to a control data from the system controller 311. A decoding audio output circuit 414 outputs the decoded audio data from the audio decoding circuit 413. A video decoding circuit 415 decodes the video data selected by the stream parser 412 in response to a control signal of the system controller 311. A decoding video output circuit 416 outputs the decoded video data from the video decoding circuit 415. A timing controller 410 generates timing control signals to control the operations of the parts of the audio/video decoder 315 under the control of the system controller 311.

The audio decoding circuit 413 must be provided with decoding elements corresponding to a linear PCM system, an MPEG system, an AC-3 system and a compression coding system. The linear PCM system and compression coding system require additional elements to reproduce the audio data recorded in the inventive DVD-Audio. Namely, the decoding elements are provided to reproduce the audio data formed by sampling frequency, quantization bits and audio channels according to the present invention. Also provided is a stream selector to distribute the audio data corresponding to the decoding elements.

A digital processor (High-bit High-sampling Digital Filter) 316 filters audio data from the audio/video decoder 315 under the control of the system controller 311. An audio output circuit (High Performance Digital to Analog Converters and Analog Audio Circuitry) 117 converts the audio data from the digital processor 316 into an analog signal. A video output circuit (NTSC Encoder Video Digital to Analog Converter's Analog Video Circuitry) 318 encodes video data from the audio/video decoder 315 in NTSC, converting the video data into an analog video signal.

Referring to FIGS. 29 and 30, the data reproduced from the disk through the pickup device 312 is transferred to the data

receiver 314 to analyze it and correct an error in it, and is applied to the audio/video decoder 315. The data produced from the data receiver 314 is applied to the input buffer 411 of the audio/video decoder 315. The stream parser 412 selects a  
5 required stream according to a control data of the system controller 311, and analyzes the stream to deliver the video data to the video decoding circuit 415 and the audio data to the audio decoding circuit 413.

The audio decoding circuit 413 transforms the audio data  
10 from the stream parser 412 according to the requirements of the system controller 311. The audio decoding circuit 413 must include the decoding functions to decode audio data of both DVD-Video and DVD-Audio. The video decoding circuit 415 decodes and transforms the input video data. The video data transformation  
15 means sub\_title process, pan\_scan, etc.

The decoded audio and video data are respectively transferred to the decoding audio and video output circuits 414 and 416, and are finally transmitted outside in synchronism with timing control signals of the timing controller 410. The  
20 decoding audio output circuit 414 adjusts the decoded audio data to the transmission format between the digital devices. The audio data generated from the decoding audio output circuit 414 is transferred to a different audio/video system or computer.

As shown in FIG. 29, the audio/video decoder 315 follows the  
25 specification of the DVD-Video when processing video signals, and carries out both the inventive algorithm and the audio decoding algorithm according to the specification of the DVD-Video. Thus, the audio decoding circuit 413 contains the linear PCM and DTS algorithms of the audio specification of the DVD-Video, and  
30 therefore both DVD-Video and DVD-Audio may be reproduced.

In this case, the algorithm required for the audio decoding of the DVD-Video indicates linear PCM decoding(1) + AC-3 decoding + MPEG decoding while the algorithm required for the audio  
35 decoding of the DVD-Audio indicates linear PCM decoding(2) + coding data decoding (Pseudo-Lossless Psychoacoustic Decoding).

Hence, the linear PCM algorithm in the DVD-Video is included in the linear PCM algorithm according to the present invention. The decoding algorithm employed in the DVD-Video and DVD-Audio includes the functions as expressed by Eq. 3, carried out by the audio decoding circuit

Eq. 3

Audio Decoder = Linear PCM Decoder(2) + Pseudo-Lossless Psychoacoustic Decoder + AC-3 Decoder + MPEG Decoder.

Thus, such an apparatus for playing both DVD-Video and DVD-Audio detects the VIDEO\_TS and AUDIO\_TS of the inserted DVD to set the audio decoding mode. The audio data of the DVD-Audio with the video data eliminated is shown in Table 24.

Table 24

Sampling Frequency	Number of Quanti- zation Bits	Bit Rate per Channel	Number of Channels	Required Data Capacity
48KHz	16bits	768Kbps	8ch	5.99Gbyte
	20bits	960Kbps	8ch	5.76Gbyte
	24bits	1.152Mbps	8ch	5.53Gbyte
96KHz	16bits	1.536Mbps	6ch	5.53Gbyte
	20bits	1.920Mbps	5ch	5.76Gbyte
	24bits	2.304Mbps	4ch	5.53Gbyte

The compression coding system specified in the DVD-Video may compress data at a maximum of 448Kbps. The sampling frequency to



allow compression is 48KHz, and the number of quantization bits to allow compression is 16bits. Hence, the amount of data to be handled is limited, and the compression ratio is about 10:1. Therefore, it is unsuitable for audio data, especially in view of sound quality. If the compression algorithm is a dolby AC-3 algorithm, the quantization system is 16 bit linear PCM, the sampling frequency is 48KHz, the maximum number of channels to record at is a maximum of 6ch (one of the audio channels having a subwoofer channel containing audio data below 200Hz and using .1 of that channel), and possible bit rate is 192Kbps-448Kbps. The dolby AC-3 algorithm is very limited in the number of quantization bits, the sampling frequency, and the high compression ratio, resulting in serious degradation of sound quality and is thus unsuitable for audio use exclusively. In addition, when the compression algorithm is MPEG2 algorithm, the quantization system is 16 bits-24 bits linear PCM, the sampling frequency is 48KHz, the maximum number of channels to record is 8ch (one of the audio channels having a subwoofer channel containing audio data below 200Hz and using .1 of that channel), and the possible bit rate is 64Kbps-912Kbps. This algorithm has a high quantization bit number for possible coding and a high channel number to record, but the sampling frequency is limited and the compression ratio high, thereby causing degradation of sound quality.

However, assuming that the transfer rate is 10.08Mbps and the time for reproducing is 80 minutes for the DVD-Audio, the linear PCM audio is achieved as shown in Table 25. Furthermore, even in the case that the sampling frequency is 44.1KHz, 88.2KHz and 176.4KHz, the PCM audio may have similar values as those shown in Table 25.

Table 25

	Sampling Frequency	Number of Quanti- zation Bits	Bit Rate per Channel	Number of Channels	Required Data Capacity
5					
	48KHz	16bits	768Kbps	13ch	5.99Gbyte
10					
	48KHz	20bits	960Kbps	10ch	5.76Gbyte
		24bits	1.152Mbps	8ch	5.53Gbyte
15		16bits	1.536Mbps	6ch	5.53Gbyte
	96KHz	20bits	1.920Mbps	5ch	5.76Gbyte
		24bits	2.304Mbps	4ch	5.53Gbyte
20		16bits	3.072Mbps	3ch	5.53Gbyte
	192KHz	20bits	3.840Mbps	2ch	4.61Gbyte
25		24bits	4.608Mbps	2ch	5.53Gbyte

Employing DTS in the compression coding system, the quantization uses 16bit, 20bit or 24bit linear PCM, a sampling frequency of 48KHz, 44.1KHz, 96KHz, 88.2KHz, 192KHz or 176.4KHz, the maximum number of channels to record is 13ch, and the compression ratio is about 4:1. The DTS compression coding has a high quantization bit number and sampling frequency with a reduced compression ratio, keeping high sound quality.

As described above with reference to FIGS. 27 and 29, the audio or audio/video player determines the kind of DVD by

checking if effective data is stored in the AUDIO\_TS directory. Namely, the DVD-Audio player performs the reproducing function or not according to whether is effective data stored in the AUDIO\_TS directory. The audio/video player as shown in FIG. 29 performs the audio or video playing function according to whether effective data stored in the AUDIO\_TS directory.

FIG. 31 describes the operation of the inventive concept with reference to the audio/video player as shown in FIG. 29. An inserted DVD is checked by the system controller 311 in steps 511, and the content of the AUDIO\_TS directory is read in step 513. In step 515, it is checked whether there is effective data stored in the AUDIO\_TS directory. If the inserted DVD is a DVD-Video, there is no effective data in the AUDIO\_TS directory. Namely, the DVD-Video has the AUDIO\_TS directory, but it is empty. However, if the inserted DVD is a DVD-Audio, the AUDIO\_TS directory contains the information on the positions of the audio data as shown in FIGS. 10 to 18C.

Detecting effective data in the AUDIO\_TS directory in step 515, the system controller 311 determines the inserted disk as being a DVD-Audio in step 517. In step 519, the position of the AMG as shown in FIGS. 10 and 11 is located by reading the AUDIO\_TS directory. Then, the pickup device 312 is moved to the position of the AMG in the DVD in step 521, where the AMG is read to confirm the information on the places storing the entire audio data. As shown in FIGS. 10 and 11, the AMG contains the information on all audio titles stored in the DVD-Audio as well as the attribute and position information of each title.

In step 523, the system controller 311 checks whether there is a demand for reproducing a specific audio title. The demand is made by the user or a command stored in the DVD-Audio. Detecting the demand to reproduce a title, the system controller 311 locates the position of the title in the disk according to the position information obtained from the AMG in step 525, and in step 527, moves the pickup device 312 to the position of the ATSI\_MAT of the title to read it. In step 529, the information

of the ATSI\_MAT as shown in FIGS. 15 to 18C is analyzed to determine the reproducing algorithm by discovering the kind and attribute of the audio title to play. In step 531, the audio decoding circuit 413 of the audio/video decoder 315 is set to the selected audio data from the DVD-Audio according to the reproducing algorithm. The information required to set the audio decoding circuit 413 are the audio coding mode, the sampling frequency, the quantization bit number and the channel number. Finally, the selected title is decoded by the audio decoding circuit 413 played in step 533.

On the other hand, if there is no effective data in the AUDIO\_TS directory in step 515, the system controller 311 determines the inserted disk as being a DVD-Video, and in step 537, the position of the VMG is located by reading the VIDEO\_TS directory. Then, the pickup device 312 is moved to the position of the VMG in the DVD in step 539, where the VMG is read to confirm the information on the places storing the entire video data. Thereafter, if there is a demand to reproduce a title, the video, sub-picture and audio data of the selected title are played according to the information stored in the VTSI\_MAT.

Likewise, a DVD-Audio player, which only reproduces data from a DVD-Audio, also performs the steps 511 to 533 for the DVD-Audio, but stops the playing operation for a DVD-Video.

After setting the audio decoding circuit 413 according to the information stored in the ATSI\_MAT, the system controller 311 analyzes the audio pack stored in the data area of a DVD-Audio from step 533 going through the steps as shown in FIG. 32.

In step 611, the system controller 311 commands a decoding operation of the audio decoding circuit 413, and in step 613, controls the stream parser 412 to transfer the received audio data to the audio decoding circuit 413 provided with the corresponding audio algorithm. Then, the audio decoding circuit 413 decodes the received audio data according to the algorithm set by the system controller 311. Here, the system controller 311 checks the operational state of the audio decoding circuit

413 in step 615. Detecting an abnormal state of the audio decoding circuit, the process proceeds to step 621 to control the decoding circuit 413 to stop the decoding operation, and the stream parser 412 is controlled to stop transferring data. Then, after performing the repair algorithm according to the abnormal state, the process is returned to step 611.

However, if the audio decoding circuit 413 performs the decoding operation normally in step 615, the decoded audio data is output through the decoding audio output circuit 414 in step 617. Thereafter, the operational state of the audio decoding circuit 413 is checked again in step 619. Detecting the abnormal state, the process proceeds to the step 621, or otherwise the process is returned to decode the next audio data. When the audio stream is fully decoded by the audio decoding circuit 413, the system controller 311 controls the digital processor 316 and audio output circuit 317 to convert the decoded audio data into an analog signal.

Thus, the inventive DVD includes a VIDEO\_TS and AUDIO\_TS directory to make it possible to distinguish a DVD-Audio from a DVD-Video by checking effective data stored in the AUDIO\_TS directory. The DVD-Audio may be recorded with the audio data sampled at a maximum of 192KHz and quantized by 24bits. Further, audio channels may be extended greatly. Therefore, by reproducing the audio data in the DVD audio, it is possible to reproduce an audio signal of high quality which is suitable for multi-channel music. The number of channels limited by the data transfer speed, the sampling frequency and the quantization bit number is extended by using a coding algorithm.

In the case where the linear PCM data sampled at the sampling frequency of 192KHz is divided into the linear PCM data of 96KHz and the data of 192KHz so that the data of 96KHz is recorded by the lossless psychoacoustic coding, the DVD of the present invention records the audio titles at the sampling frequency of 192KHz in the AUDIO\_TS directory by linear PCM lossless coding, and records the video titles at the sampling

frequency of 96KHz in the VIDEO\_TS directory by linear PCM coding. The DVD-audio player reads the AUDIO\_TS to demodulate the data by the lossless psychoacoustic coding, and mixes it with the data of 96KHz to reproduce it into the data of 192KHz. The  
5 DVD-video player reads the VIDEO\_TS directory to reproduce the data of 96KHz. That is, by recording one title into the AUDIO\_TS and VIDEO\_TS separately, the DVD-audio player may reproduce the data at 192KHz and the DVD-video player may reproduce the data at 96KHz.

10 Furthermore, in the case where the music data sampled at the 44.1KHz for an existing CD is provided to the DVD, the music data of 44.1KHz should be converted into the music data of 48KHz in order to provide it by using the conventional DVD-video format. Undesirably, however, the audio data may be degraded during the  
15 conversion. The DVD according to the present invention can support the audio frequency sampled at 44.1KHz in DVD-audio format. Thus, it is possible to record the audio data as it is without conversion of the sampling frequency and provide it together with the video data, thereby providing the audio sound  
20 of high quality.

Preferably, a general DVD-video player should be connected to the DVD-audio player which can reproduce the 24-bit data of 192KHz, since the general DVD-video has a specification inferior to that of the DVD-audio.